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(54) Process for the preparation of aluminoxanes.

(57) Process for preparing aluminoxanes from trialkylaluminium compounds and an ultrasonically produced water dispersion.

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PROCESS FOR THE PREPARATION OF ALUMINOXANES

This invention relates to a process for the preparation of aluminoxanes - also referred to as alumoxanes - which are useful in combination with transition metal compounds to prepare polymerization catalysts.

Aluminoxanes find use as components in polymerization and oligomerization catalysts. Aluminoxanes have been prepared by reacting a hydrocarbon solution containing trialkylaluminium with hydrated crystalline salts such as $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ as described in "Mechanism of Stereochemical Control in Propylene Polymerization with Soluble Group 4B Metallocene-Methylalumoxane Catalysts, J. Am. Chem. Soc., 1984, 106, 6355-6364), and $\text{Al}_2(\text{SO}_4)_3 \cdot 9\text{H}_2\text{O}$ as described in "Zirconium Catalysts Polymerize Olefins Faster," Chem. & Eng. News, July 4, 1983, 29-30 and U.S. patent specification 4,544,762. This technique requires guarding against the possibility of contaminating the aluminoxanes with small amounts of the crystalline salts which can act as poisons when the aluminoxanes are used in polymerization catalysts. In U.S. patent specification 3,300,458, a method is described for preparing aluminoxanes which consists of contacting trialkylaluminium dissolved in a hydrocarbon solvent with a second hydrocarbon stream which has been saturated with water by contacting the solvent with water in a solvent saturator. In this technique, however, since the amount of water present in the hydrocarbon is small, being limited by the solubility of water in the solvent, relatively large amounts of solvent are required to prepare the aluminoxanes. Manyik et al in "A Soluble Chromium-based Catalyst for Ethylene Trimerization or Polymerization", Journal of Catalysis, 47, 197-209, (1977) also describe the use of water wetted solvent and further describes the use of the direct addition of water to a dilute solution of trialkylaluminium. However, the water addition must be done very slowly in order to prepare the aluminoxane rather than aluminium hydroxide.

It is an object of the present invention to use a minimal amount of solvent and to allow for a relatively rapid reaction rate to be used over a broad range of temperatures.

Accordingly, the invention provides a process for the preparation of aluminoxanes which process comprises mixing a first solution of a trialkylaluminium compound in a liquid, dry, inert hydrocarbon solvent with a second solution of a liquid, inert, hydrocarbon solvent having water ultrasonically dispersed therein wherein the trialkylaluminium compound and the water react to produce an aluminoxane.

The aluminoxanes are well-known in the art and are polymeric aluminium compounds which can be represented by the general formula $(\text{R}-\text{Al}-\text{O})_n$ which is a cyclic compound and $\text{R}(\text{R}-\text{Al}-\text{O})_n\text{AlR}_2$, which is a linear compound. In the general formula, R is preferably an alkyl group having in the range of from 1 to 5 carbon atoms, such as, for example, methyl, ethyl, propyl, butyl and pentyl and n is an integer from 1 to about 20. Generally, in the preparation of aluminoxanes from trialkylaluminium and water, a mixture of the linear and cyclic compounds is obtained.

The aluminoxanes are prepared according to the invention by reacting a C_1 to C_5 trialkylaluminium compound (R_3Al) in a suitable solvent with water which has been ultrasonically dispersed in a suitable solvent. Illustrative examples of suitable trialkylaluminium compounds are trimethylaluminium, triethylaluminium, tri-isopropylaluminium, tri-n-propylaluminium, tri-isobutylaluminium and tri-n-pentylaluminium. Methyl and ethyl groups are preferred. Methyl groups are particularly preferred.

The inert solvents that can be used to dissolve the trialkylaluminium or disperse the water are well known and include the saturated aliphatic compounds such as butane, pentane, hexane, heptane, octane, isooctane and the purified kerosenes; the cycloaliphatics such as cyclobutane, cyclopentane, cyclohexane, cycloheptane, methylcyclopentane and dimethylcyclopentane; alkenes such as butene, hexene and octene; cycloalkenes such as cyclohexene; and the aromatic solvents such as benzene, toluene and xylene. The major requirements in the selection of a solvent are that it be liquid at the reaction temperature, that it does not react with the trialkylaluminium compound or with water or interfere with any subsequent reaction wherein the aluminoxanes are used in polymerization catalysts. The solvents must be oxygen-free. Hydroxyl groups, ether groups, carboxyl groups, keto groups and the like adversely affect preparation of the aluminoxanes.

The aluminoxanes can be produced over a wide range of temperatures, from above the melting point of the solvent to up to the boiling point at the pressure used. Generally, temperatures below about 50 °C are used. Relatively low temperatures can be utilized with the appropriate solvent, say, -100 °C or lower. Pressures are not critical and will typically vary from atmospheric to about 35 bar.

There are numerous pieces of equipment available commercially containing ultrasonic transducers that can be used to ultrasonically disperse the water in the solvent. The ultrasonic baths that are readily available commercially provide suitable means for dispersing the water in the solvent. The amount of water to be dispersed in the organic solvent ranges from just above the limits of solubility of water in the solvent to less than about 5% by weight. There are several alternative methods that can be used to prepare the

aluminoxanes according to the present invention. The preferred method is to first ultrasonically disperse the water in a suitable solvent, and, while maintaining the ultrasonic power, add the solution of trialkylaluminium to the water dispersion, allowing the trialkylaluminium to react with the water to produce the aluminoxane. Alternatively, the ultrasonic power can be shut off prior to adding (with mixing) the trialkylaluminium solution. The key here is to carry out the reaction prior to the breakup of the water dispersion. The dispersion can be maintained for relatively long periods of time by cooling the dispersion. Very satisfactory results have been obtained by cooling the dispersion to dry ice (-78.5 °C) temperatures. The above reaction should be carried out in an inert, for example nitrogen or argon atmosphere.

After reaction, the solvent can be stripped and the aluminoxane isolated as a stable white powder. Preferably, however, the aluminoxane is left dissolved in the solvent, which can then be reacted with suitable transition metal compounds to form polymerization catalysts.

In general, the molar ratio of trialkylaluminium to water will be about 1:1 although variations of this ratio can occur without adversely affecting the aluminoxane product, i.e., the Al/water molar ratio can vary between 0.65:1 to 2:1, preferably 0.75:1 to 1.25:1.

The following examples further illustrate the invention.

Example 1

The following represents a typical preparation of an aluminoxane at ambient conditions by the process of the instant invention.

Dry toluene (20 ml) was placed in a bottle fitted with a nitrogen purge system and the bottle was placed in an ultrasonic bath (Branson). The ultrasonic was started and water (4 mmol) was added through a hypodermic syringe. After a five min period of sonification, 4 mmol of trimethylaluminium (as a 25% by weight solution of trimethylaluminium in toluene) was added. Sonification was continued during the reaction to prepare the aluminoxane as evidenced by gas evolution.

Example 2

Example 1 was repeated in substantially the same manner except that the ultrasonic bath was maintained at 0 °C.

Example 3

Example 1 was repeated in substantially the same manner except that the ultrasonic bath was maintained at a temperature of 50 °C.

Example 4

Dry toluene (20 ml) was placed in a bottle fitted with a nitrogen purge system and the bottle was placed in the ultrasonic bath. Water (4 mmol) was injected and sonification was continued for six min. The bottle was then removed and chilled in a dry-ice acetone mixture. After chilling, 4 mmol of trimethylaluminium (as a 25% by weight solution in toluene) was injected and the reaction to the aluminoxane was allowed to go to completion.

Example 5

1-Octene (50 ml) was placed in a nitrogen purged bottle which was placed in an ultrasonic bath at ambient temperature. Approximately 4 mmol of water was injected. After 3 min of sonification to disperse the water about 4 mmol of trimethylaluminium (as a 25% by weight solution in toluene) was added and the reaction to the aluminoxane was allowed to go to completion.

Example 6

Part A -Oligomerization catalysts according to the teachings of co-pending application Serial No. 896,700, filed on even date were prepared and tested.

To the aluminoxane solutions of Examples 1-5, 0.5 mmol of bis(cyclopentadienyl)zirconium dichloride were added with stirring to prepare the catalysts. To examples 1-4 were added 50 ml of 1-octene, Example 5 already containing 1-octene from the aluminoxane preparation. The resultant mixtures were heated to 40 °C for 30 min before removing samples for gas chromatographic analysis. The conversions of 1-octene to oligomers, presented in table 1 hereinafter, are highest where the aluminoxanes had been prepared at a temperature in the range of from -100 °C to +50 °C.

TABLE 1

15	<u>Aluminoxan from</u>	<u>% Conversion of 1-octene</u>
	<u>Example</u>	
20	1	49.8
	2	65.0
	3	11.7
	4	93.5
25	5	61.9

Part B - Various amounts of water were used to prepare the aluminoxane and the results on the dimerization catalysts were measured.

The catalysts were prepared as follows: 20 ml of dry toluene were placed in a bottle fitted with a nitrogen purge system and the bottle was placed in an ultrasonic bath (Branson). The ultrasonic was started and the designated amount of water was added through a hypodermic syringe. After a five minute period of sonification, 4 mmol of trimethylaluminium (as a 25% by weight solution in toluene) was added. After the reaction was completed (as evidenced by termination of gas evolution), 50 ml of 1-octene and 0.5 mmol of bis(cyclopentadienyl)zirconium dichloride was added and the mixture was heated to 40 °C. After 30 min, samples were removed for analysis. The results, presented in table 2 hereinafter, show that the conversions of 1-octene are highest when the molar ratio Al to water ranges from 0.65:1 to 2:1.

TABLE 2

45	<u>Water,</u> <u>mmol</u>	<u>Al/water</u> <u>molar ratio</u>	<u>Conversion</u> <u>of 1-octene, %</u>
	3.0	0.75	37
50	3.2	0.8	57
	3.6	0.9	72
	3.9	0.975	67
55	4.0	1.0	49
	4.2	1.05	29
	4.7	1.175	12

Claims

1. A process for the preparation of aluminoxanes which process comprises mixing a first solution of a trialkylaluminium compound in a liquid, dry, inert hydrocarbon solvent with a second solution of a liquid, inert, hydrocarbon solvent having water ultrasonically dispersed therein wherein the trialkylaluminium compound and the water react to produce an aluminoxane.
2. A process as claimed in claim 1 wherein the alkyl moiety of the trialkylaluminium compound is an alkyl group having in the range of from 1 to 5 carbon atoms.
3. A process as claimed in claim 2 wherein the alkyl moiety is a methyl or ethyl group.
4. A process as claimed in any one of the preceding claims wherein a molar ratio of trialkylaluminium compound to water in the range of from 0.65:1 to 2:1 is used.
5. A process as claimed in claim 4 wherein the molar ratio is in the range of from 0.75:1 to 1.25:1.
6. A process as claimed in claim 5 wherein the molar ratio is about 1:1.
7. A process as claimed in any one of the preceding claims which is carried out at a temperature in the range of from -100 °C to +50 °C.
8. A process as claimed in any one of the preceding claims wherein said first solution is added to said second solution while maintaining ultrasonic power.

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